

THE BRADFORD OIL DISTRICT
OF PENNSYLVANIA

By

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BY CHAS. A. ASHBURNER, ASSISTANT, SECOND GEOLOGICAL SURVEY
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(Read at the Baltimore Meeting, February, 1879.)

THE Bradford Oil District lies in the northern part of McKean County, Pa., and the southern part of Cattaraugus County, N. Y. Although petroleum was first found in the *producing sand* in 1871, it was not until the early part of the year 1875 that a productive horizon was acknowledged to exist, even by those most largely interested in the production of the crude oil.

It has been reported to me that the first well drilled in the valley of the Tuncangewant Creek (commonly called Tuna Creek) was drilled by F. E. Dean and brothers in 1865. This well was located on the Shepherd farm, near the present site of Custer City. One hundred and sixty feet of drive pipe was used, and the hole was drilled to the depth of 900 feet.

The *producing sand* at Custer City is found about 1130 feet below the level of the railroad track. The Shepherd farm well was therefore abandoned over 200 feet above the top of the oil sand.

The next well was drilled by the Dean brothers on the Clark farm at Tarport. Drilling was stopped at a depth of 605 feet, or over 400 feet above the top of the oil sand.

In the year 1862 the old Bradford well, since known as the Barnsdall well, was drilled to a depth of 200 feet with a spring pole, and then abandoned. In the spring of 1866 the citizens of the village of Bradford concluded to club together and sink the Barnsdall well deeper. It was drilled to a total depth of 875 feet, or to within 150 feet of the Bradford *producing sand*. All of these wells were drilled with the expectation of finding the Venango County oil, and at about the same depth below water-level as at Oil City. They were all utter failures, and the old Bradford well, drilled to a depth of 200 feet in 1862, has as much claim to have been the first *oil* well in the Bradford District as any of those which were subsequently drilled by the Dean brothers.

The *first well* sunk to the Bradford sand was drilled by Mr. James E. Butts, Hon. C. H. Foster, and Mr. Job Moses, with a few others,

under the name of the Foster Oil Company. This well was situated on the Gilbert farm, two miles northeast of Bradford. "Slush" oil was found at a depth of 751 feet, and the producing sand was struck at 1110 feet in the month of November, 1871. The daily production was 10 barrels. From the time when the sand was found in the Foster Oil Company's well to December, 1874, no wells were drilled that amounted to anything.

On December 6th, 1874, Messrs. Butts and Foster struck the oil sand in what is known as the Butts well, No. 1, on the Archy Buchanan farm, two and a half miles northeast of Bradford. This well started off with a daily production of 70 barrels, and was really the first well that attracted the attention of the oil men to the possibility of finding a profitable oil district in the county.

The unparalleled growth of the field is evidenced by the fact that in December, 1878, four years from the completion of the Butts well, the average daily production of crude oil was 23,700 barrels, or about $\frac{4}{5}$ ths of the total daily production of the State of Pennsylvania.

Geological Position of the Bradford Producing Sand.—The early drillers in the territory regarded the oil as coming from the same geological horizon as that occupied by the "Third Sand" along Oil Creek, in Venango County. Inconsistent as this idea was with known facts in the geology of Northwestern Pennsylvania, the *producing sand* was named the "Third Sand," and the determination of a "First" and "Second" sand was left to the driller. No careful examination was made of the "sand pumpings," but from the way the drill pierced the strata two sand horizons were located. The upper sand, about 600 feet above the producing sand, was named the "First Sand;" the lower one, 300 feet above the same horizon, was named the "Second Sand."

The opinion which had been frequently expressed by expert geologists that there was little probability of finding the Oil Creek sands north of the Philadelphia and Erie Railroad was denied on the basis of what the driller regarded as overwhelming evidence. As far as nomenclature went the comparison between the Venango and McKean County oil rocks seemed perfect. Along the Allegheny River, in the former county, the drill had proven the existence of three distinct sand horizons producing petroleum, which had long been known as the "First," "Second," and "Third" sands, the latter being the most productive.

One mile above Oil City, in Venango County, the top of the "Third Sand" is 528 feet above ocean level. At Bradford, which

is 64 miles, north 55 degrees east, of Oil City, the top of the producing sand is only 414 feet above ocean level. If the producing sand in the two localities was the same, there would be a dip in the sand from Oil City to Bradford of (528-414) 114 feet. Between these two places the surface rocks have a persistent dip to the southwest, which averages about 14 feet per mile. This estimate is based on the identity of the Second Mountain Sand, the bottom of which north of Oil City is about 1290 feet above ocean level, with the Olean conglomerate, the bottom of which at Bradford is 2170 feet above the same datum.

The interval between the outcropping conglomerates and the geological horizon of the Oil Creek "Third Sand" probably varies but little between the two points, so that the stratum, whatever it be, which occupies the horizon of the "Third Sand" in McKean County should be found at Bradford at about water-level. But the top of the sand which produces the petroleum at Bradford is found 1030 feet below water-level.

In Venango County, according to Mr. Carll, Assistant in the oil regions, the average distance from the top of the "First Sand" to the bottom of the "Third Sand," is 315 feet. In McKean County, I find from a study of a number of well records, that the average distance from the top of the First Sand, so called, to the bottom of the so-called "Third," or producing sand, is 660 feet. Here then are two facts which cannot be denied, if the Oil Creek "Third Sand" is geologically the same as the Bradford sand: First, the Bradford sand is over a *thousand feet* lower than facts would lead us to suppose, and, second, the groups of oil rocks in McKean County are over *three hundred feet* too thick. Again, if the Venango and McKean oil sands were the same, of course the whole rock series would have to thicken very much to the northeast.

The accompanying chart of columnar sections shows that the Pocono, No. X, Catskill, No. IX, and probably the upper Chemung rocks, No. VIII, thicken very materially from Bradford south to Ridgway. If the strata from the Second Mountain Sand to the Oil Creek "Third Sand" did not remain approximately constant from Oil City to Bradford, as we have supposed, there would be many more reasons to assign a thickening to the southwest rather than to the northeast.

Mr. Carll, in the early part of 1876, published the fact that the Bradford *producing sand* was probably 1000 feet below the Oil

Creek "Third Sand." Facts since obtained show this to have been a close estimate.

To make a comparison of the rocks passed through in the two districts, it was necessary to have complete and authenticated records. No accurate register of the rocks has ever been kept by any of the producers in the Bradford district. This fact can readily be accounted for when it is remembered, that with the exception of the wells at State Line and Limestone, N. Y., the bulk of the production comes from one horizon. The difference in the strata is so slight, that except by a close examination of the sand pumpings, it is impossible to distinguish any change in the succession of the sedimentary deposits.

In December, 1877, Professor J. P. Lesley appointed Mr. Arthur Hale to the special work of obtaining a correct record of the Dennis & Co.'s well, No. I, which was about to be drilled on the high summit about three-quarters of a mile southwest of Bradford. This well was completed in the early part of 1878. The measurements were made with great care, and wherever the rock was found to change a specimen or specimens were secured for future study. The depth of the well is 1719 feet. The elevation of the floor of the derrick above ocean is 2055 feet, Bradford station on the Erie Railway (now N. Y., L. E. and W. Railway) being 1444 feet. This record is without doubt the *longest detailed and accurately measured* record of any oil well in the United States. Deeper wells have been drilled, but no record has ever been kept so accurately as this one to such a depth. A complete description of the record is contained in a paper which I read before the American Philosophical Society, September, 1878.

The top of the well is stratigraphically 115 feet below the bottom of the Olean Conglomerate, which is the lowest member of the Coal Measure conglomerate, No. XII, and which caps the highest summits in the vicinity of Bradford.

The Mauch Chunk shales, No. XI, if present in this part of the county, are represented by the shales immediately underlying the Olean Conglomerate. They cannot be more than 5 or 10 feet thick.

The strata pierced in this well may be grouped as follows :

Pocono (Vespertine), No. X,	. . .	132 feet.
Catskill (Ponent), No. IX,	. . .	250 "
Chemung (Vergent), No. VIII,	. . .	1337 "
Total,		1719 feet.

The total thickness of No. X is about 230 feet, allowing 7 feet for the shales of No. XI, immediately underneath the Olean.

The following is a condensed description of the Dennis record :

Pocono Formation, No. X.

	Thickness.	Depth.
Surface clay,	4 feet to	4 feet.
Olive gray shale,	11 "	15 "
Gray sandstone,	33 "	48 "
Gray shale,	19 "	67 "
Blue and gray sandstone, shale and slate, .	49 "	116 "
Gray sandstone,	16 "	132 "

Catskill Formation, No. IX.

	Thickness.	Depth.
Red shale,	6 feet to	138 feet
White and gray sandstone,	59 "	197 "
Red shale "Paint Rock,"	18 "	215 "
Gray sandstone containing a few pebbles, .	23 "	238 "
Bluish slate,	77 "	315 "
Gray sandstone,	5 "	320 "
Red slate,	8 "	328 "
Gray sandstone and slate,	39 "	367 "
Red shale, mottled,	15 "	382 "

Chemung Formation, No. VIII.

	Thickness.	Depth.
Gray slate,	8 feet to	390 feet.
Dark and gray sandstone,	45 "	435 "
Fine sandstone and slate,	216 "	651 "
Gray sandstone and slate,	61 "	712 "
Red sandstone,	10 "	722 "
Dark slate,	20 "	742 "
Sandstone and chocolate shale,	63 "	805 "
Gray slate and sandstone,	201 "	1006 "
Red slate and shale,	14 "	1020 "
Gray sandstone and slate,	36 "	1056 "
Gray and yellow sandstone, "First Sand," so called,	25 "	1081 "
Gray sandstone and slate (oil show in lower part),	44 "	1125 "
Gray slate,	175 "	1300 "
Brown sandstone,	17 "	1317 "
Slate,	28 "	1345 "
Brown and gray sandstone, "Second Sand," so called,	36 "	1381 "
Gray slate, with occasional sand beds, . .	283 "	1664 "
Brown sand, "Third Sand," so called, or Bradford <i>producing sand</i> ,	54 "	1718 "
Slate and sandstone,	1 "	1719 "

Three hundred and twelve specimens were obtained of the strata encountered in the Dennis well.

For convenience of study I have placed a portion of each specimen in a homœopathic vial, half-inch diameter. These vials are placed on their sides, and piled one upon another, and placed in three walnut cabinets, each cabinet containing 104 bottles. Each bottle is separated by a small strip of tin from the adjoining bottle, so that any one may be removed for examination without disturbing the others. The space in each cabinet which contains the samples is $5\frac{3}{4}$ feet long and $2\frac{1}{2}$ inches wide.

To the right of the rock column I have placed a columnar section drawn to scale, so that the specimens may be referred directly to their vertical position in the well record. It will be noticed that the bottles themselves are not placed according to scale, but are piled directly one upon another, irrespective of the interval which separates them in the record. If the specimens had been placed to scale the total length of the section would have been 45 feet instead of $17\frac{1}{4}$ feet as at present. The size of the cabinets would have been awkward, and no material advantage would have been gained. I have given the above description, from the fact that I believe it to be the best method for the study of well records in connection with specimens of the borings.

The *producing sand* in the Dennis well is 54 feet thick. The sand is of about the same degree of coarseness as the ordinary beach sand along the Jersey coast, and contains comparatively little cementing material. The sand is finer and closer in texture than that of any other oil-producing territory in Pennsylvania. It is more homogeneous in section, and has a more constant character over a wider area than any other oil-sand.

These facts have much to do with the small percentage of risk which the driller experiences in obtaining "dry holes." The Bradford is the surest and safest district in which to operate.

In January last there were 112 wells completed in the territory, of which 8 or $7\frac{1}{10}$ th per cent. were "dry holes." The percentage of "dry holes" in the other districts of the State was $29\frac{1}{10}$ th, or 7 wells out of 24 completed.

In the Bradford district, from December 1st, 1877, to December 1st, 1878, there were 2018 wells completed, of which 87 were "dry holes," or $4\frac{3}{10}$ ths per cent.

The percentage of "dry holes" in Pennsylvania, exclusive of the Bradford district, during the same year was $24\frac{7}{10}$ ths.

In the Haskill well at Smethport, fifteen miles southeast of Bradford, a sand was struck at 1345 feet, and was reported to be 12 feet thick. The sand which at present is producing about two barrels of oil a day in the Haskill well was found at a depth of 1718 feet, and is 18 feet thick. Drilling was continued to 124 feet below the lower or producing sand. The Smethport producing sand, by most of the producers, is considered to be the same as the Bradford sand. From a careful study which I have made of a number of surface sections and well records in northern McKean County, I have come to the conclusion that the upper sand in the Haskill well is the representative of the Bradford sand, and that the lower or producing sand in this well lies 360 feet geologically lower than the great productive horizon of the Bradford district.

The Smethport oil horizon is interesting, from the fact that it is the *lowest* geological horizon at which petroleum has been found in Pennsylvania. I first announced the discovery of this fact in a paper, which I read before the Engineers' Club of Philadelphia, February 16th, 1878, on the "Oil Sands of Pennsylvania." At that time, the sand had not been found at Smethport, but had been pierced by the drill in a well at Sartwell in an adjoining township.

I have named the rocks in the Dennis well after a careful study of the same series throughout McKean and Elk counties, embracing a territory 45 miles to the south of Bradford, west into Warren County, and east and southeast into Potter and Cameron counties. A careful examination of the fossil forms in this district from the Chemung up into the lower productive Coal Measures has been made, but the means which the fossils afford for stratigraphical determinations are extremely limited.

Palæontologically considered, the rocks from the base of the Olean Conglomerate, No. XII, to the bottoms of the deepest valley, some 800 feet in all, are essentially one group incapable of subdivision. They contain in all eighteen Waverly species, seven Chemung species, and one of Carboniferous type. I have grouped the rock series mainly from lithological determinations, which undoubtedly lead to the most reliable and accurate conclusions, when sufficient sections can be had for comparison. Having determined the relation of the *producing sand* at Bradford to the overlying strata, I next sought for some constant horizon which should afford the best means of comparing distant sections. This was of importance in order to ascertain the approximate depth below the surface of the Bradford sand in any territory adjacent to the developed district, in which

petroleum should be drilled for. The rock most constant in its general character in McKean and Elk counties seems to be the Olean Conglomerate.

Between this conglomerate and the oil-bearing sand there is no stratum or series of strata, with possibly the exception of the red shale bands of the Catskill, No. IX, and Chemung, No. VIII, which can furnish a reliable guide to the oil prospector.

The sandy measures in the 1000 or 1500 feet immediately overlying the oil-sand at Bradford, are poor guides in looking for the oil-sand in new or wild-cat territory. They lead to confusion, error, and disappointment. There is no guide which the driller considers more infallible than the so-called "First" and "Second" sands. It is true that in a limited territory, there are distinct sand strata 300 and 600 feet respectively above the Bradford sand, but I believe it impossible to determine the position of the oil-sand by an arbitrary location of these upper sands.

One important fact, which is too often overlooked, is that the rocks may thicken or thin between two constant horizons in comparatively short distances, so that allowances must be made, either plus or minus, in estimating the proper depth to drill in order to strike the *producing sand*.

The accompanying chart of columnar sections shows the position of the Bradford *producing sand* below the Olean Conglomerate at Bradford, in the Haskill well at Smethport, in the Wilcox wells, in the Bear Creek well, in the Silver Creek well, and in the old Dickinson or Ridgway well. The horizon of the sand in the three latter wells is probably about the same depth below the bottom of the Red Catskill as it is in the Wilcox wells. Although the bottom of the Olean Conglomerate in the vicinity of these different wells is found at varying elevations, yet I have placed it in the drawing on the same horizontal line, for convenience of comparing the underlying strata.

It will be noticed that the Pocono formation, No. X, and Red Catskill, No. IX, thicken very much south from Bradford. As a consequence the Bradford oil-sand horizon at Ridgway would be found nearly 600 feet further below the Olean rock than it is at Bradford. This fact has a very important practical bearing. The Bear Creek well, which was drilled to a depth of 1998 feet, and the Silver Creek well, which is 1760 feet deep, have both been abandoned long before the Bradford sand could possibly be reached. I

do not mean to say that if these wells were drilled to the proper depth, they would prove productive. Not at all, but I do assert that they should be much deeper to strike the Bradford sand if it underlies this portion of Elk County.

These two wells form examples of many that I could cite where the money spent in drilling has been more than thrown away. They prove nothing and only tend to condemn the territory as "dry" without any facts to support such a conclusion. Can it be denied that geological work is of practical use to the oil prospector?

The following table gives the thickness of the several formations shown in the chart, together with the tidal elevation of the Bradford sand. The well records have been continued up to the bottom of the Olean Conglomerate, where the drilling was commenced below that horizon, by surface observations.

The geological position of the top of each well in McKean County, in the table, may be found by subtracting the distance to the top of the Bradford sand from the sum of the overlying formations. In making the same estimate of the wells in Elk County, the total depth of the well must be taken instead of the distance to the top of the Bradford sand, since this horizon was not reached by the drill.

A section is not given on the chart of the Halings, Hukill, Curn, or Ernhout & Taylor (No. 2) wells.

It will be noticed that between Bradford and Smethport the strata from the Olean rock to the Bradford sand maintain almost a constant thickness. From Bradford southwest to the Hukill well, which is one and a half miles northeast of Ludlow station, the Pocono, No. X, thickens about 100 feet, while the other formations remain about the same as in the Dennis well. In the Wilcox wells, No. X is about the same thickness as in the Hukill well. The greatest amount of change in the two counties takes place between the Wilcox wells and the Bear Creek well. In this distance of $8\frac{1}{4}$ miles the interval from the bottom of the Olean to the top of the Catskill thickens to the south at the rate of $28\frac{1}{2}$ feet per mile. The same rocks between the Bear Creek and Ridgway well thicken to the south at the rate of $26\frac{1}{2}$ feet per mile. From the Wilcox wells to the Ridgway well the Red Catskill, No. IX, thickens at the average rate of $4\frac{1}{2}$ feet per mile.

If it was not for the geological fact that the formations thicken in Elk County rapidly to the south, the Bear Creek well would be deep enough to have encountered the horizon of the Bradford sand.

	Distance in miles from Dennis well.	Direction from Dennis well.	THICKNESS OF FORMATIONS, IN FEET.					Elevation of top of well.	Depth to top of Bradford oil-sand.	Elevation of top of Bradford oil-sand.	Total depth of well.
			No. XI.	No. X.	No. IX.	No. VIII, to top of Bradford oil-sand.					
McKEAS COUNTY.											
Dennis well, Bradford.....	13.39	S. 8° 30' E.	No. XI, in McKean Co., has not been absolutely recognized, but is probably represented by 5 to 10 feet of shales under the Olean conglomerate.	250	247	1282	2655	1664	391	1719	
Hollings well, Kinzua Creek.....	13.77	S. 49° 00' E.					1625	1545	80	1650 (?)	
Snethport well.....				260			1590			2004	
Haskill well, Snethport.....	14.92	S. 44° 30' E.		260	250	1305	1552	1345	207	1861	
Hukill well, N.E. of Wetmore.....	15.72	S. 44° 30' W.		343	260	1299	1846	1950 (?)	104	2011	
Wilcox well, No. 3.....	21.25	S. 4° 00' W.		330	263	1290	1666	1685	19	1850	
Coburn well.....	21.65	S. 10° 45' W.		325	260 ±	1284 ±	1900	1944	44	2263	
Embout and Taylor, No. 2.....	22.80	S. 11° 00' W.		340			1730	1880	150	2000	
ELK COUNTY.											
Bear Creek well.....	29.37	S. 4° 30' W.	45	520	313	No. VIII, to bottom of well. 1655	1595	Not reached.			1998
Silver Creek well.....	29.92	S. 6° 00' W.	45 ±			797	1615	"			1760
Ridgway well.....	36.8	S. 6° 40' W.	45 ±	675		70	1383	"			772

The distance drilled below the top of the Bradford sand may be found by subtracting the depth to the top of the sand from the total depth of the well.

The elevation of the bottom of the Olean Conglomerate in the vicinity of the Wilcox wells is 1879 feet; at Ridgway the same geological horizon is 1746 feet above tide, so that the *average dip* of the bottom of No. XII between the two places is about $8\frac{1}{2}$ feet per mile. The southern dip of all the rocks below the Olean would be greater than $8\frac{1}{2}$ feet per mile on account of their thickening to the south.

Dip of the Bradford Sand.—The *producing sand* from the Four Mile district, which is in Cattaraugus County, N. Y., about seven miles northeast of Bradford, toward Bradford averages 12 feet per mile south 50° west. From Bradford toward Shepherd Run the average dip per mile is 11 feet, south 25° west. From Tarport north to State Line, to Limestone, the dip varies from 15 to 19 feet per mile to the north. This change of dip to the north near the State Line has doubtless influenced the shape of the valley eroded by the Allegheny River.

The development which has been made at State Line and at Limestone is outside of the line which I have drawn on the map as the approximate boundary of the Bradford district, in October, 1878. The wells at these two places have been excluded because their characteristics are quite different, and they seem to form an outlying patch of the main district. The total length of the Bradford territory proper, northeast and southwest, is over 17 miles, while its maximum breadth northwest and southeast is about 8 miles.

Production of the Bradford District.—The growth of this oil-field has been so rapid and so different from the other districts in Pennsylvania that I have thought it might be of interest to the Institute to make some general statements as to its production.

DAILY PRODUCTION OF BRADFORD DISTRICT COMPARED WITH THE TOTAL DAILY PRODUCTION OF THE STATE.

	State.	Bradford.	Proportion.
1874, December,	27,682 bbls.	75± bbls.	
1875, { June,	23,207 "	125± "	
{ December,	23,254 "	149 "	
1876, { June,	24,120 "	800 "	$\frac{3}{1000}$
{ December,	25,390 "	1,800 "	$\frac{10}{1000}$
1877, { June,	37,693 "	3,449 "	$\frac{9}{1000}$
{ December,	40,518 "	8,000 "	$\frac{19}{1000}$
1878, { June,	40,575 "	16,000 "	$\frac{39}{1000}$
{ December,	42,538 "	23,700 "	$\frac{56}{1000}$

Three years ago from last December Bradford produced less than one-hundredth of the total production of Pennsylvania. In Decem-

ber, 1878, Bradford produced over one-half of the entire production of the State.

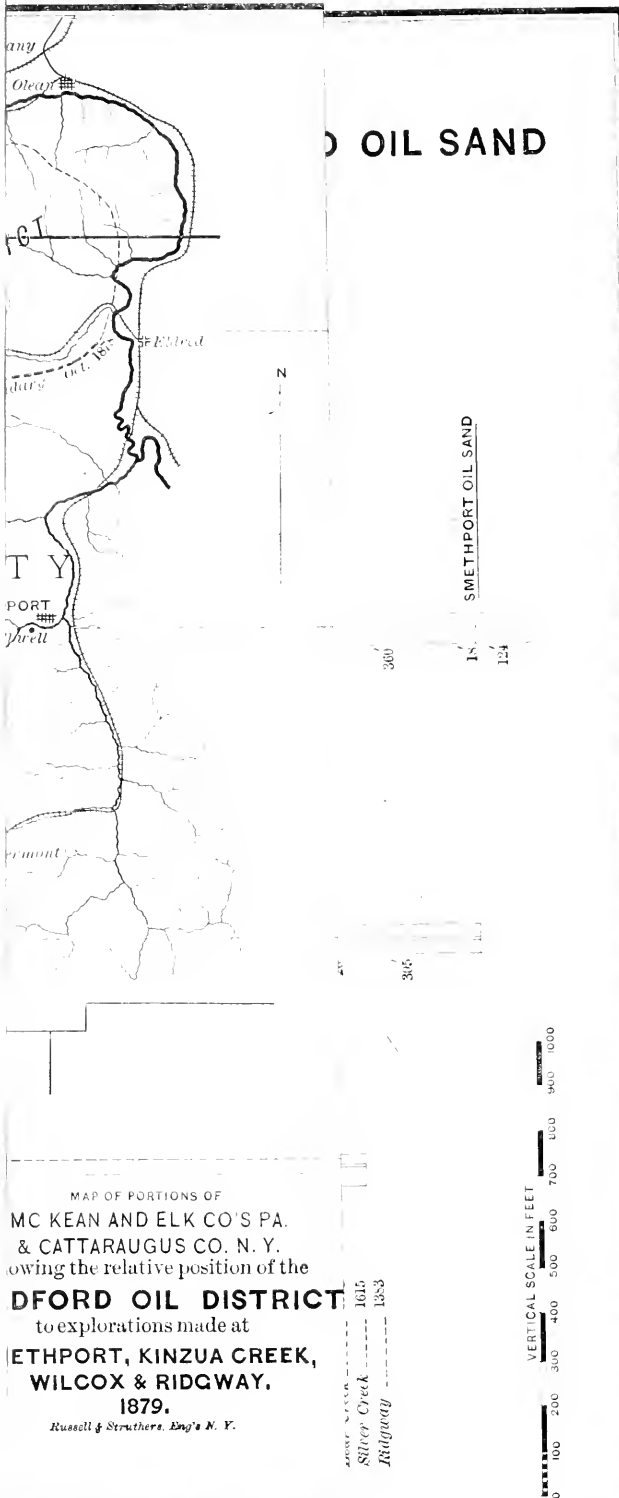
The following table gives the total production in the State and the Bradford district for 1876, 1877, and 1879:

	Bradford.	State.
1876,	382,768 bbls.	8,968,906 bbls.
1877,	1,465,481 "	13,135,671 "
1878,	6,208,746 "	15,165,462 "
Total for three years.	8,056,995 bbls.	37,270,039 bbls.

The total production of McKean and Cattaraugus counties from the discovery of petroleum in 1871 up to the first of the present year, would amount in the aggregate to about eight millions one hundred thousand (8,100,000) barrels of oil.

The average daily production of the 3000 wells in the Bradford district during last month (January) was 25,000 barrels or $8\frac{1}{3}$ barrels per well. The average daily production per well of those which were completed during the month was $17\frac{1}{2}$ barrels.*

* My conclusions are based on statistics taken from Stowell's Petroleum Reporter of Pittsburgh.



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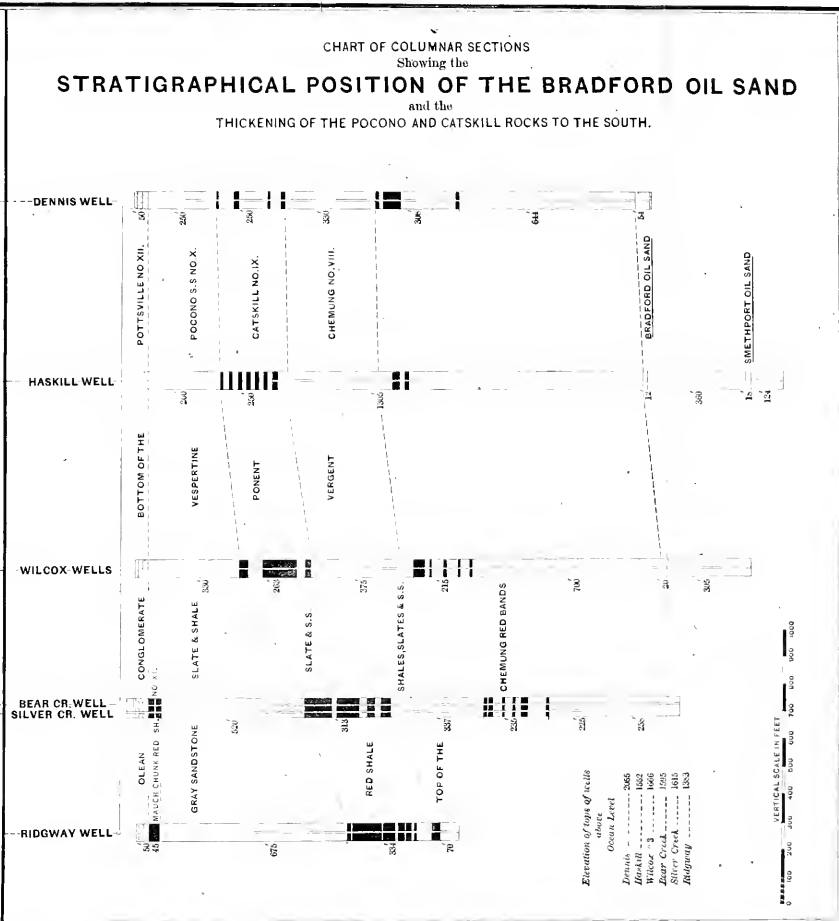
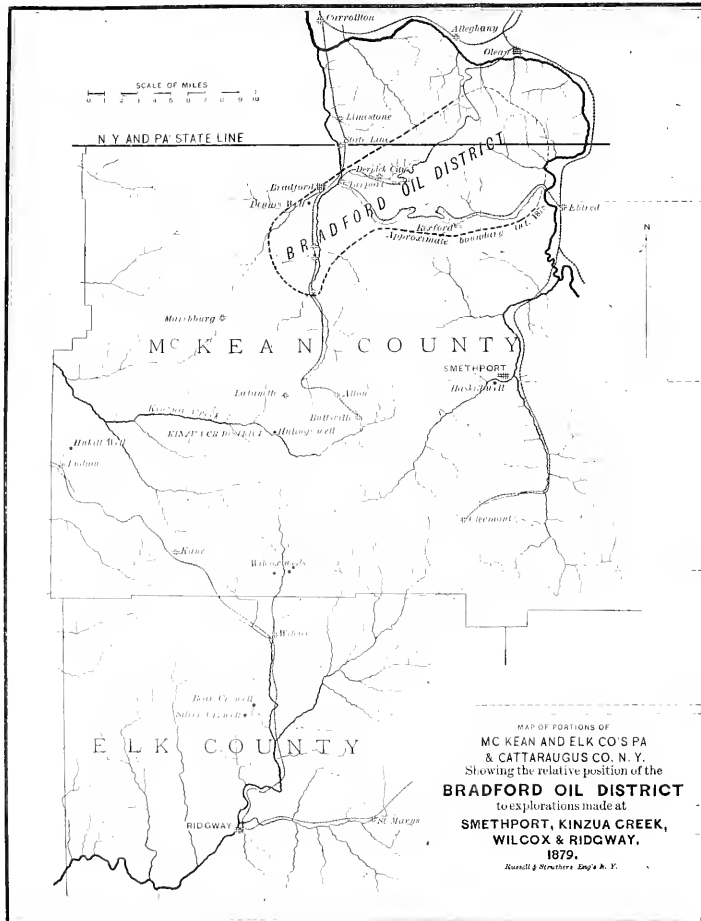
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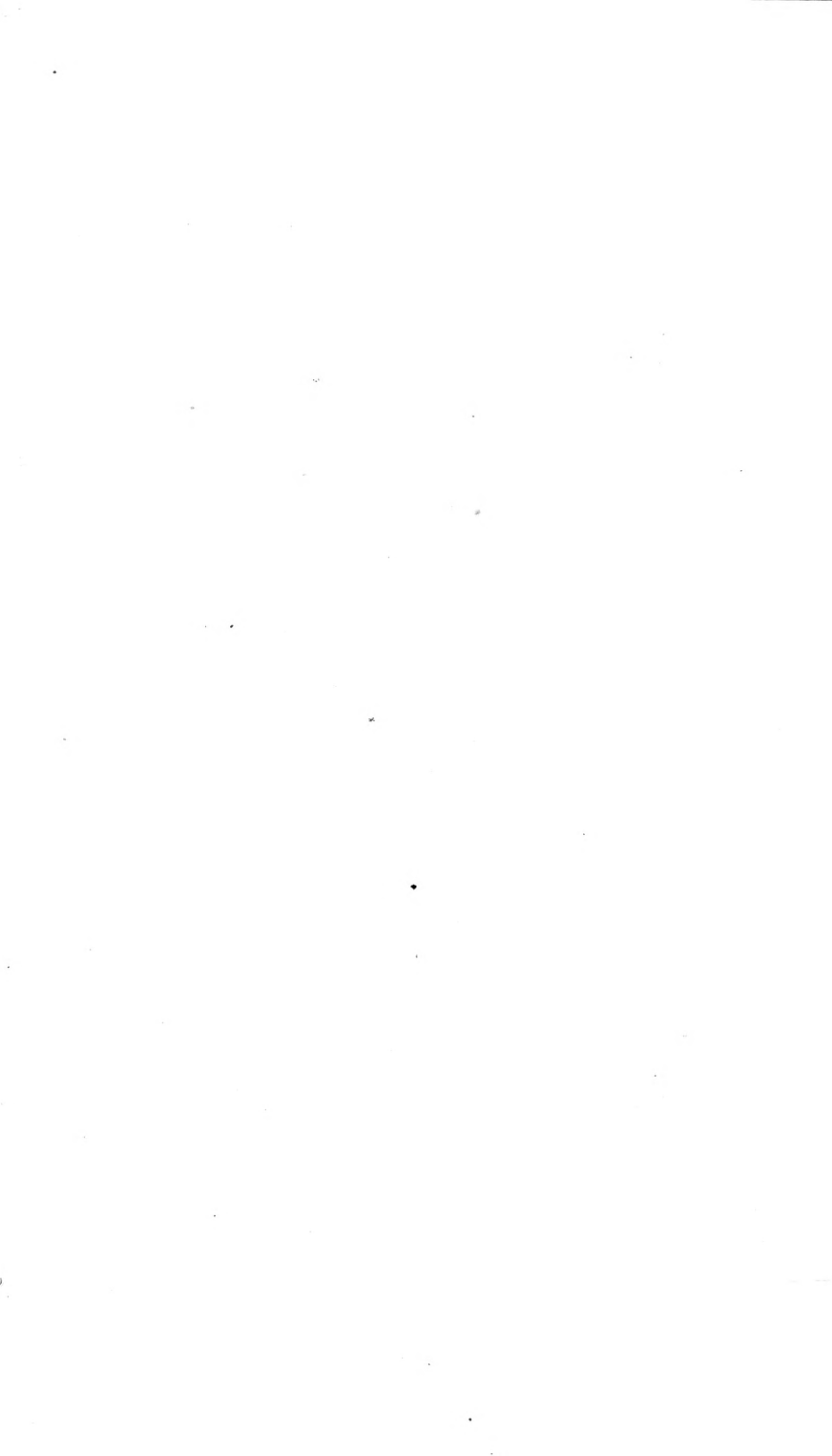
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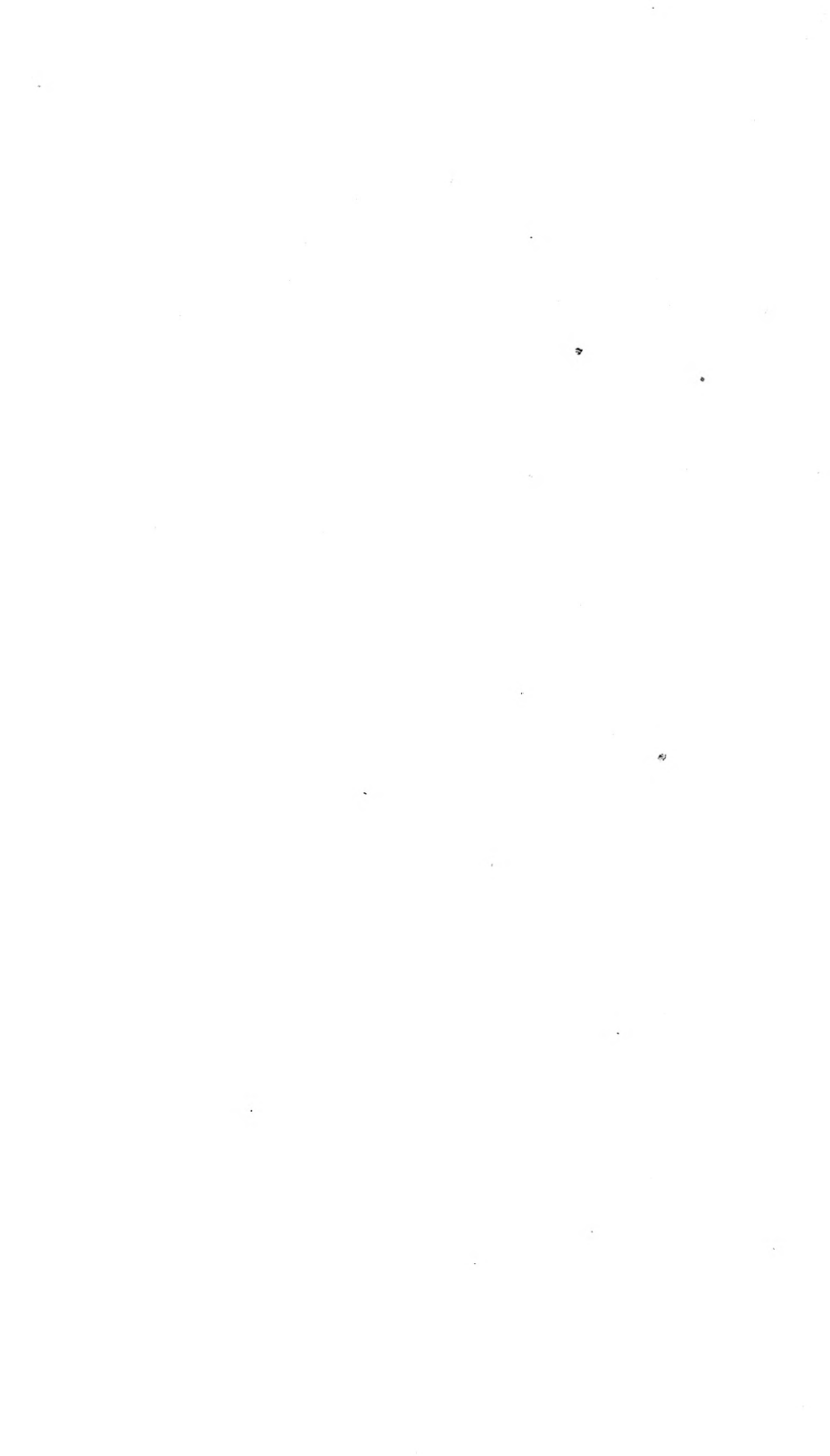
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